Shay Reversing Gear

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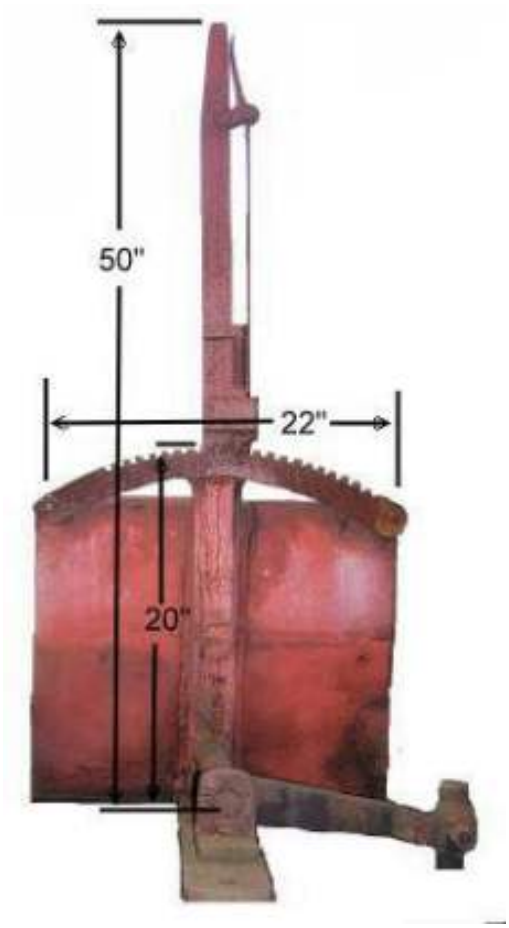
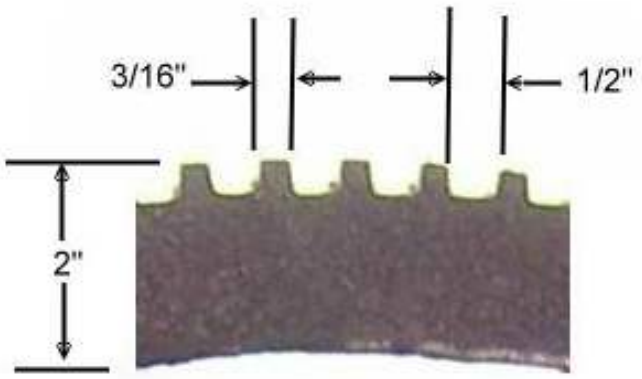
The reversing gear is another one of those pieces I've been putting off. The reason for the postponement was that I wanted to duplicate the prototype, especially the sector plates with a lot of teeth but didn't have good photos or dimensions from the prototype. Reverse gears of several shays were photographed and measured on a visit to Cass in September 2003. There are several variations of reversing gears including steam powered reversing gears on some of the larger shays.

Cass 10: This photo shows the reversing gear on Cass 10. The cab is off so it's easy to get a good view. This is the reversing gear that I chose to model.

And the dimensions .....



Teeth dimensions



Arm ---- 12.5" between centerlines.

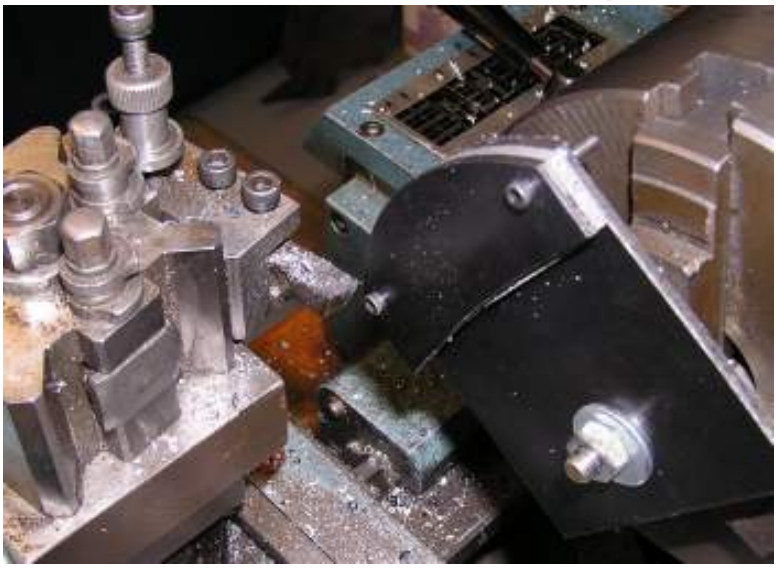
Johnson bar lever ---- 14.25 between centerlines.

The Cass No 10 reversing lever moves through an arc of a little over 50 degrees (measured by holding a protractor on the front view photo above). The reverse shaft on my shay engine rotates 32 degrees. Kenneth specified an arm on the reversing gear longer than the Johnson bar lever thus reducing the 32 degrees to a bit less than 30 degrees at the reversing gear handle. I think the reason that Cass No 10 lever moves about 50 degrees while the angle on my Shay is closer to 30 degrees is that the the link levers are longer on my shay than on Cass No 10.

I wanted a bit more lever motion so I could have a few more of those neat teeth so I decided on a total lever motion of about 40 degrees. The arm and Johnson bar lever lengths will be adjusted as necessary to make things work out.

Cass 10 has 2 sector plates (the curved pieces with the teeth). There is a heavy vertical bar welded to one of the sector plates which is further steadied with the thin rectangular plate. I decided to copy Kozo Hiraoka's design and use only one sector plate with the other set of teeth cut in the stand, a vertical plate running down to the floor.

Stand & Sector Plate: 12 gauge material was selected for the stand and sector plate. I started with a 3" wide by 3.5" high piece for the stand and screwed a smaller piece for the sector plate to it as shown on the right. The hole is centered and 3/4" from the bottom and tapped 1/4"-28. There is a aluminum spacer plate sandwiched between the sector plate and stand to permit turning the inside of the sector pate without marking the stand. Those are 4-40 screws holding the pieces together.



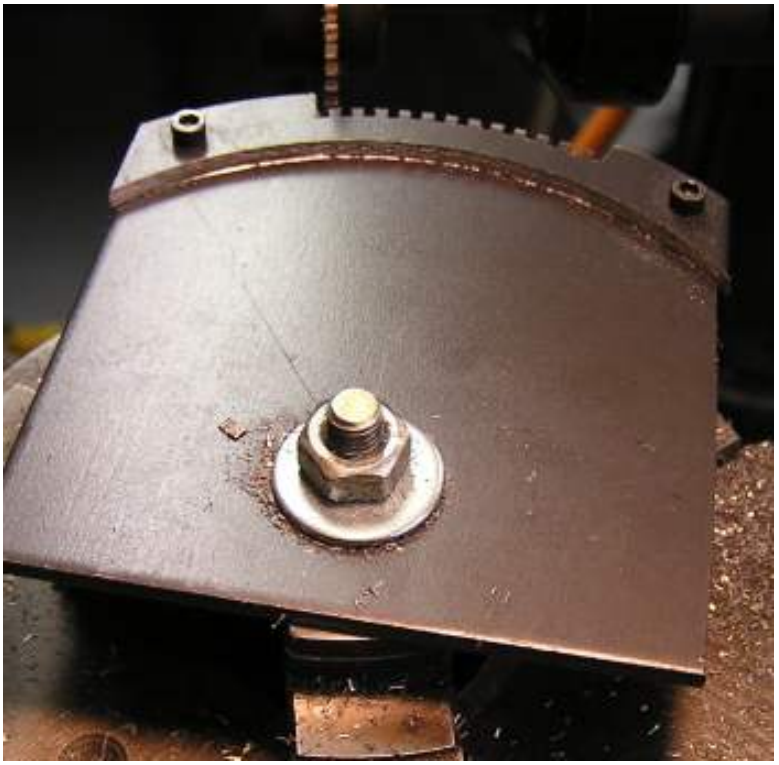
A long 1/4-28 bolt was chucked in the lathe and the stand screwed on the bolt. A washer and nut were added to secure the plates. The outside was then turned to 2.5" radius as shown on the right.

The inside was turned to 2.125". The sector plate was too wide

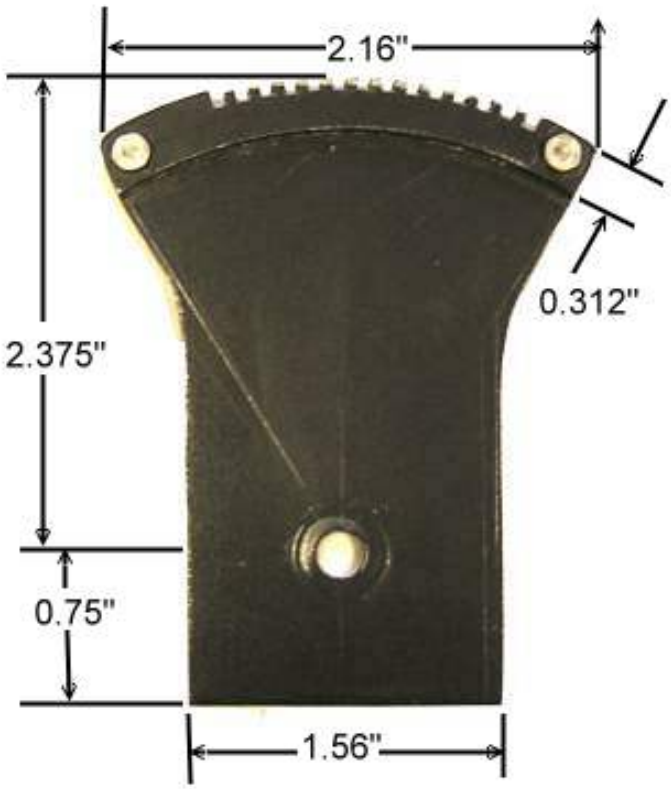
at this point but I decided to cut the teeth and then finish the turning (maybe a premonition).

The lathe chuck (with the stand and sector plate still attached) was transferred to an adaptor on the rotary table. The rotary table was then mounted on the lathe/mill table and a 1/16" wide slitting saw mounted in the milling head. The plan was to use a 2.5 degree pitch and cut the teeth 0.70" deep. That proved too close spacing so I went to 3 degrees pitch and cut the teeth twice as deep ---- planning to remove the extra 0.070" later. When doing the second set I found the the chuck wasn't tightened on the rotary table and it had rotated some screwing up the pattern --- so it was a third attempt with the teeth 0.21" deep. Sure was glad I had the extra width on the sector plate.

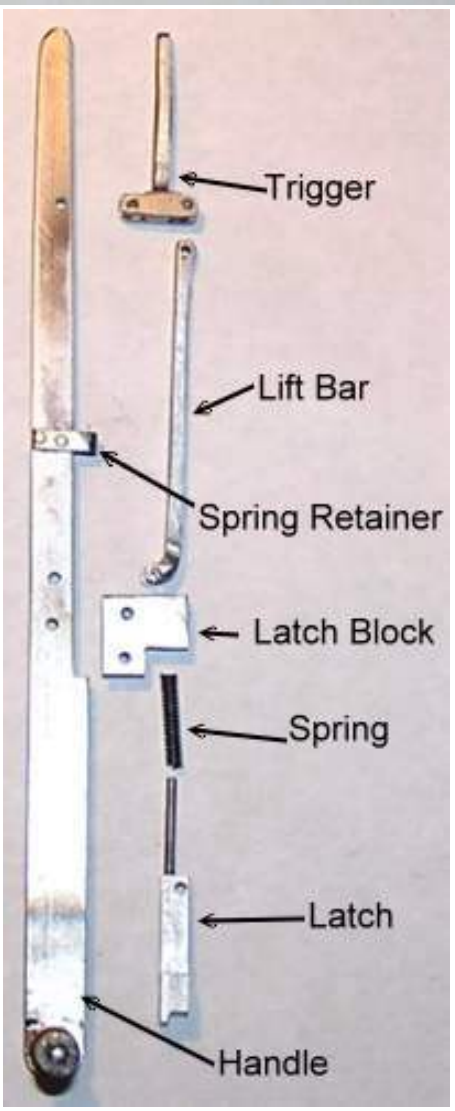
This is how things looked after the 0.14" excess tooth length was eliminated.



The chuck with the plates was than moved back to the lathe and 0.14" turned off the outer edge (the part on each side of the teeth) to match up with the teeth. Next, the sides were trimmed to match the gear teeth and new holes drilled to hold the sector plate to the stand. This shows the finished stand and sector plate with dimensions.



This shows all the parts of the stand. The two spacers (0.128" long) were cut from 1/4" rod. The base and bearing were cut from 1/4" bar stock. The initial plan was to solder the stand to the base but 4-40 screws into the edge of the base proved to be sufficient.



Handle: The photo on the right shows the various parts of the handle system. The handle was made from 1/8" X 3/6" CFS bar. It is 6.5" long from the center of the 1/4" axel hole at the bottom to the tip.

The spring retainer was cut from 1/8" X 1/4" bar. It has a hole to allow the 1/16" rod on the latch to slide through and the latch to move up and down. The retainer was screwed to the handle(#1 brass screws), silver soldered and then the screw heads filed off.

The latch was cut from 3/8" CFS bar stock. The rod out the top is 1/16" retained by a drop of Loctite.

The spring is from the scrap box --- OD < 1/8", ID > 1/16".

The lift bar was cut from 1/8" X 1/4" CFS bar stock.

The trigger was cut from 1/4" X 1/2" CFS bar stock

The assembled handle mounted in the stand is shown on the right. The latch block is screwed to the handle with 1-72 button head screws --- left over from the tanks.

The prototype uses clevis pins with cotter pins. The clevis would have to be about 1/16" diameter --- too small to drill a hole for a cotter. Instead, 1/16" roll pins were used for the clevis pins. The outer holes --- those in the trigger and the lower end of the lift bar were drilled 0.70" to allow free movement with the pins a tight fit in the inner holes.

Arm Johnson Lever & Link: The last parts are the arm, the Johnson bar lever and the link between the arm and lever. One thing that had troubled me was that the link had to have two degrees of freedom like a ball joint or universal. The link used on Cass 10 is shown on the right. Note the ball joints on each end of the link.

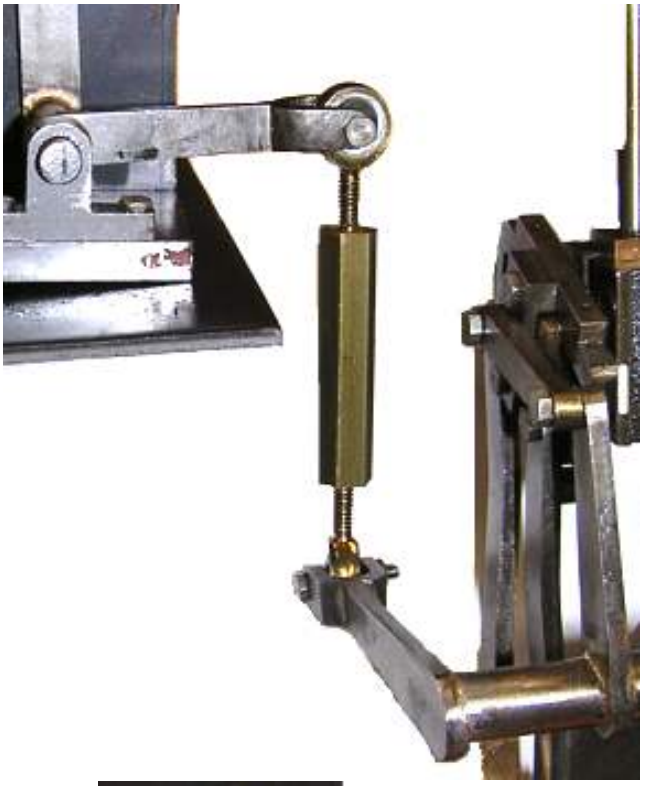
Arm & Ball Joint: This photo shows the partially completed arm and a ball joint.

The ball joint is from McMaster-Carr - part # 60645 K 611. It has a 1/8" hole and 6/32 shank. I had ordered two, one with RH thread and the other LH thread. The one with LH thread was shipped from another warehouse and hadn't arrived when this photo was taken. I also obtained a 6-32 LH thread tap. The plan is to make a coupling threaded LH in one end and RH in the other end. One ball joint will be screwed into each end and the link length adjusted by turning the coupling.

That is the partially fabricated arm in the photo The end is made from 1/8" X 3/8" CFS bar stock that was heated and bent in a U shape. The main part of the arm is also made from 1/8" X 3/8" stock and silver soldered into a shallow 1/8" wide slot milled in the end of the U shaped piece. The arm was then ground and filed to make it somewhat tapered and the sides of the U shaped end thinned to about 3/32" The arm was left extra long during the fabrication to make handling easier. The last step was to drill the 1/4" axel hole and then cut off the end. I used a somewhat shorter arm than specified by Ken --- 1.75" between the centerlines.

Completed Reversing Gear: The arm and handle are silver soldered to the 1/4" diameter axel.

The color of the photo is weird --- incandescent lamps.



Link with Arm and Johnson Bar Lever: The Johnson bar lever is 2.25" between the center lines. With this length about 95% of the available rotation of the reverse shaft is used at the extremes of the reverse lever. This is by design --- I didn't want to force the reverse shaft to the stops.

The coupling is made from 5/16" hex stock. I'm going to remake it with 1/4" stock to cut the size slightly (didn't have 1/4" stock). A lock nut is required on one end --- a standard nut on the RH threaded ball joint. The screws through the ball joints are turned 1/8" diameter from 3/16" hex stainless stock. The ends are turned down to 0.112" and threaded 4-40. Double nuts will be used on the ends to lock them in place as on the prototype.

Finished Reversing Gear with Link: The ball joints on the link permit considerable flexibility in the position of the reversing gear. I'm going to select the position after the boiler is in place.

Update - Different Mounting Arrangement: I've got to the point of figuring out where to locate all the controls. Earlier I'd planned to mount the reversing lever fairly close to the side of the cab. I'm now trying to fit in the steam brake valve, the reversing gear and the throttle lever, all of which are located near the engineer. Locating the three controls as close as possible to the position in the prototype seems to work the best.

A platform is built around the reversing gear on Cass 5. The platform covers the arm and link and makes a flat surface to mount the engineer's chair. The photo on right shows the platform to be 18" high (I used the original photo and enlarged it to read the tape measure).

This photo shows the platform to be about 35" wide and the lever to be located about 30" from the cab wall.

The stand for the reversing gear I'd made was too high and the arm and handle were located too close together. After fooling around with the possibilities I decided to make a different base, mount the base about 1" below the floor and move the arm away from the lever.

Dropping the base below the floor leaves most the space under the platform empty. That might be a good place to mount the atomizer regulator. I'm also going to test an igniter of the type used in a gas grill to see if it will work to relight the burner if it should go out. If the igniter works, the button part could also be mounted under the platform. The atomizer pressure gauge would work nicely in place of the engineer's seat. (That piezoelectric igniter didn't work out. An electronic igniter did work and the push button switch for that igniter was mounted in this area.. See ElectricalI page

This photo shows the new base made from 1/4' thick angle. The inside corner was squared on the mill. A longer axel was used separating the lever from the handle. One quarter inch was cut off the bottom of the stand because the stand is on top the bottom leg of the base rather than beside the base. The stand was secured to the sort leg of the angle with 4-40 screws. The short leg of the angle fits between the flanges on the frame I beam and is secured with a couple 8-32 screws.

This photo shows the reverse gear mounted to the frame. The gray piece of plywood is a model of the boiler backhead with the throttle lever. There is ample clearance between the reverse and throttle levers. The steam brake valve will mount above the rear cylinder. The steam brake lever will be above the reverse lever and below the throttle lever.

The bottom leg of the angle is wider and longer than needed. There will be some pipes running in this area and the angle might be a useful anchor point so I decided to postpone reducing the size of that bottom leg.

Shay Home
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